EFFECT OF SHADING ON TONKAN ORANGE (*CITRUS TANKAN* HAYATA)

I. The effect of shading on wind injury, fruit quality, size, and rate of fruit growth

by

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INTRODUCTION

The tonkan orange (*Citrus tankan* Hayata) is the most popular citrus species in Taiwan and occupies more than 50% of the total citrus acreage. In 1964, more than 230,000 cases of Tonkan orange which represent 72.07% of the total citrus fruit export were delivered to the foreign market.

Taiwan is geographically located along the passage of typhoons. The Tonkan orange is always under the threat of severe damage caused by the extreme high velocity wind and torrential rain whenever typhoon happens to sweep through or passes near by the Island.

In order to test the effectiveness of Acacia (*Acacia confusa* Merr.) as windbreak for citrus orchard, experimental plots were established in which Tonkan orange and Acacia were interplanted. It was then observed that orchard interplanted with Acacia produced orange of better appearance.

This paper reports the results of observations made on the effect of Acacia as windbreak and its shading effects on the wind injury, quality, size, and rate of fruit growth.

Of the many studies made on shading processes, Jawanda[8] applied the shading for the study of growth rate of sweet orange fruits; Graner[5] and Suarez[12] used shade tree for coffee; Barva[2] and Wight[15] used shade tree in tea plantation; Cunningham[3] studied shade and fertilizer requirements of cocoa.

METHOD AND MATERIAL

This experiment was conducted from January 1963 to January 1966. The orchard site was chosen near the sea cost at Tansuei of Taipei Prefecture where citrus trees are usually subject to wind damage.

Tonkan trees of 7 years old were employed for this trial. Each treatment contained one tree with 3 replications. Three treatments were employed in this study namely: whole shading, in which citrus tree was interplanted with Acacia tree in four directions; semi-shading, interplanted with Acacia in two directions only, and no shading as check.

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The methods of measurement and analysis of citrus fruits were as follows:

1. The standard used for determining wind injury is set at 5% of wind injured scurf/fruit. Fifty fruits per plot were chosen for testing.
2. Description of fruit:
   a. Weight in grams, size, height, and diameter in centimeter.
   b. Color of peel, pulp, and juice classified according to Ridgway[10].
   c. Thickness of peel in millimeter measured on fruit apex, median, and base.
   d. Thickness of segment wall measured in millimeter by Oial thickness gauge.
   e. Number of segment and diameter of axis.
   f. Number of seeds.
3. Ten fruits of each tree were examined for counting the number and size of oil glands as seen from peel. The samples were washed with water, and dried with a cloth. A thin piece of peel (0.5 mm. thick) was cut from the rind surface on the equator of fruit. Tangential slices were taken from the equator of rind and placed under microscope for examination. Slices calibrated into 0.5 cm^2 were placed over the slides, then the diameter of oil gland was measured in micron and the number of oil gland (per 0.5 cm^2) was counted.
4. Observations on the growth rate of fruit after physiological dropping were made at successive growing period. Twenty sample fruits per tree were measured in cubic centimeter which was developed by Shisa[11].
5. The percentage of sugar in juice was measured by Hitachi Hand Refractometer (0°–30° Brix degree).
6. Vitamin C, reducing sugar, total sugar, and acidity were analyzed by A. O. A. C.[1] procedures.

ENVIRONMENT OF TEST PLOT

The quality of Tonkan orange are greatly influenced by the difference of soil and meteorological conditions. Fig. 1–4 indicate the climatic factors including the the temperature, precipitation, duration of sunshine, and velocity of wind. Soil conditions under different treatments were tested for pH value, organic matter

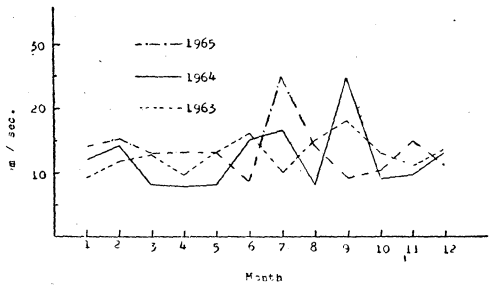

Fig. 1. Maximum wind velocity in the course of this experiment.

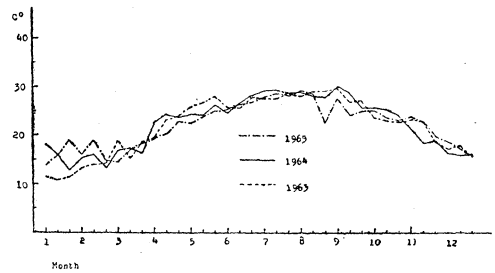

Fig. 2. Average temperature during the experiment.

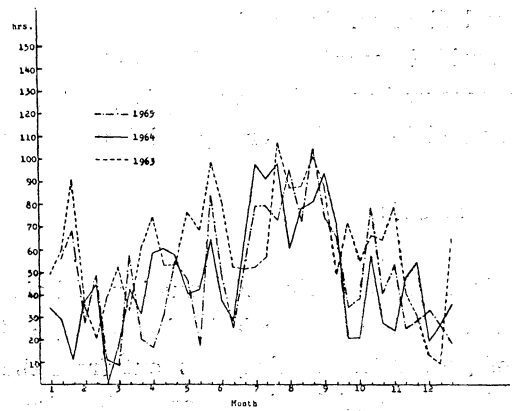

Fig. 3. Length of sun light during the experiment.

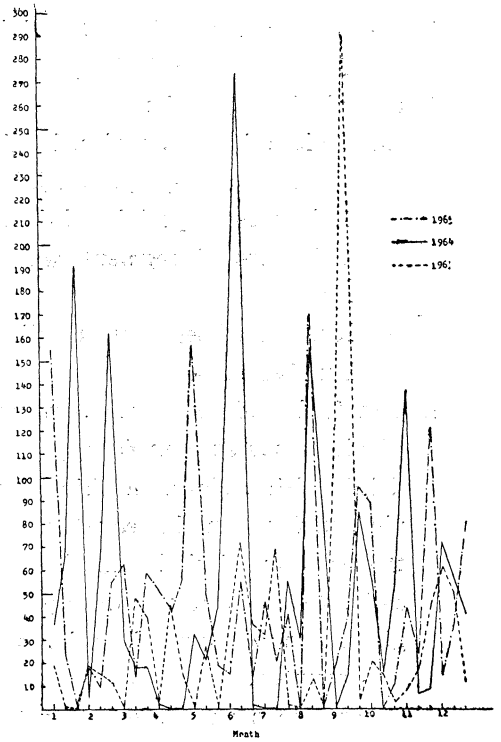

Fig. 4. Monthly rainfall during the experiment.

Table 1. Description of soil

Soil factors Treatment	pH	Organic matter (%)	Available P (ppm)	Available K (ppm)
Semi-shading	5.0	4.58	30.3	37.6
Whole shading	4.8	5.00	33.2	58.0
Check	4.8	3.88	28.8	28.8

* pH value: Glasselectrode method (Soil: Water=25:25).
Organic matter per cent: Walkley and Black's rapid titration mothod for organic matter.
Available P: Bray's P test.
Available K: Mehlich method.

content, available potassium and phosphorus as in Table 1.

Two highest wind velocities occurred during July 16 of 16.5 m/sec. (Wendy's) and September 11 of 25 m/sec. (Cloria) in 1963, and July 26 of 25 m/sec. (Harriet), August 18 of 14.3 m/sec. (Mary) in 1965, whereas no typhoon occurred in 1964. (Fig, 1)

High temperature occurs mostly between July and September, thererfore, in average, the growth rate of Tonkan is three times faster during July, August, and September, with the exception of the occurrence of drought in these months. (Fig. 2)

Long duration of sun shine mostly occur between July and September in Taiwan. This explains why the percentage of citrus fruit caused by sun scald was lower in

the shade plots during these months. (Fig. 3)

Record of the growth rate of Tonkan increased in August and September 1964 when the precipitation was high, but almost ceased to grow during dry July. These phenomena were especially true in the plot without shading. No records of growth rate in 1963 was taken. Erratic curves of precipitation show the influence of typhoon. (Fig. 4)

The properties of soil were shown in Table 1. It is interested to note that shading plots contained much higher organic matter than without shading. It was attributed to the accumulation of leaves and stems resulted from the prunning of Acacia in the winter season.

RESULTS AND DISCUSSION

1. The effect of shading on the wind injury of fruits:

The foliage of citrus tree may be greatly injured by strong winds, Taiwan is lying in the tropical and sub-tropical zone, and is crossed by the tropic of Cancer in the south. Its climate is influenced by both the Pacific ocean and the Chinese mainland and is characterized by strong-wind. So Taiwan often suffers from damages of typhoon in July to September. During this time, Tonkan orange is still in small green fruit rubbing against other twigs or branches resulting in a thin scurf closely imitating thrips markings. When the fruit is more nearly mature such a rubbing may result in a still more deep-seated scurf. Table 2. show that the percentage of wind injured scurf appeared on fruit was found less in shaded plots than those in the plots without shading. Most prominent case was found in 1963 and 1965. It was probably due to the typhoon occurred in July and September of 1963 and July and August of 1965 whereas no typhoon throughout in 1964. This observation serves as strong evidence that Acacia is an effective of windbreak, as Goto[6] reported that a well-established windbreak, combind with the use of relatively tall shade tree interplant in the coffee might have sufficient wind ptotection under certain conditions.

*Table 2. The effect of shading on the wind injury

Treatments	Wind injury**		
	1963	1964	1965
Semi shading	14.12	6.25	15.75
Whole shading	11.94	5.25	13.50
Check	25.06	14.87	27.25
L.S.D. 5%	1.7243	0.8134	0.8580
L.S.D. 1%	2.3932	1.1289	1.1910

* All data in the table are average of 8 replications.
** Percentage of scurf

2. The effect of shading on occurrence of sunburning:

The sunburning is frequently mistaken for certain diseases on citrus. Indeed, certain bark diseases frequently begin under high light intensity, the radiation of the sun either weaken or kill the bark and make it easy for microorganisms to enter. In check plot without shading, the intense radiation after injure or kill the expose portion of trunk or fruit, causing these portion to dry and peel off, resulting in sun scald condition.

The occurrence of sun scald was partially due to the rapid growth of cell of fruit skin under the high light intensity and long duration of sunshine in summer as suggested by Ogaki[9]. From the weather data observed during the three-year trial it indicated that high temperature and long duration of sunshine were found in August as given in Fig. 3. Yet less occurrence of sun scalded orange in shaded plots proved the shading effect.

3. The effect of shading on fruit quality:

Table 3 indicates that shading would significantly reduce the number of seed per fruit, which is similar to the results obtained by Webber[14]. Furthermore the number of seed per fruit was less in 1965, it probably due to the low temperature in February and March (the blossom period), which causes the formation of parthenocarpic fruit as indicated by Takahashi[13].

Table 3. The effect of shading on fruit quality

Factor \ Treatment		Semi-shading	Whole shading	check	L.S.D. 5%	L.S.D. 1%
weight gram/fruit	1964	195.490	193.333	140.520	13.16	18.26
	1965	190.400	202.400	163.300	3.421	4.748
Height (cm)	1964	6.450	6.506	5.739	0.339	0.470
	1965	6.270	6.230	5.582	0.0501	0.0697
Diameter (cm)	1964	7.320	7.229	6.534	0.327	0.454
	1965	7.180	7.340	6.691	0.0566	0.0786
Color of peel	1964	Cadmium orange	Cadmium orange	Orange	—	—
	1965	Capuci ne yellow	Capucine yellow	Orange	—	—
Thickness of rind (mm)	1964	4.05	4.04	4.12	N.S.	
	1965	3.62	3.63	3.77	N.S.	
No. of seed per fruit	1964	2.283	1.838	2.287	0.215	0.293
	1965	0.520	0.330	0.530	N.S.	
Diameter of fruit axis (cm)	1964	1.451	1.310	1.194	N.S.	
	1965	1.130	1.190	1.110	N.S.	
Thickess of segment wall (mm)	1964	0.224	0.223	0.204	N.S.	
	1965	0.196	0.198	0.202	N.S.	

Fruits from the shaded plots offer much more attractive appearance in color and thiner thickness of peel in comparison with those from check plots which is similar to the results obtained by Jawanda[8] and Webber[14].

4. The effect of shading on pulp and juice:

The juice contained in the fruit obtained from shaded plots had more acidity than those from the plots without shading as shown in Table 4. This is perhaps due to the late maturity of fruit in the shaded plots. Color of pulp and juice was not affected by shading with the exception of the amount of juice which was higher in the fruit from shaded plots than that the plots without shading. This was probably attributed to fairly high humidity under the shaded area. Similar results as stated above had also been obtained by Webber and Batohor[14].

Table 4. The effect of shading on pulp and juice of fruits

	Factor \ Treatment		Semi-shading	Whole shading	CK	L.S.D. 5%	L.S.D. 1%
Pulp	Weights gm/fruit	1964	134.49	138.32	95.99	25.96	36.03
		1965	142.20	144.30	100.30	1.982	2.751
	Pulp* %	1964	68.79	71.54	68.31	—	—
		1965	73.63	71.29	61.42	—	—
	Color of pulp	1964	Orange	Orange	Orange	—	—
		1965	Orange	Orange	Orange	—	—
	Weights gm/fruit	1964	101.141	104.56	71.29	7.54	10.46
		1965	109.30	120.60	82.10	1.514	2.102
	Juice** %	1964	51.87	54.08	50.73	—	—
		1965	57.40	56.81	50.28	—	—
	Color of juice	1964	Orange	Orange	Orange	—	—
		1965	Orange	Orange	Orange	—	—
Juice	Citric acid g/100 cc	1965	0.64	0.64	0.65	N.S.	
		1965	0.78	0.79	0.73	N.S.	
	Sugar*** %	1964	9.756	9.652	10.200	N.S.	
		1965	9.960	10.400	9.600	N.S.	
	Sugar/acid	1964	15.15	15.01	15.64	N.S.	
		1965	12.77	13.16	13.15	N.S.	
	Sp. gr.	1964	9.41	9.67	9.41	N.S.	
		1965	4.5	4.8	4.5	N.S.	
	pH	1964	3.60	3.60	3.80	—	
		1965	3.49	3.54	3.71	—	
	Vitamin c mg/100 g	1965	33.63	33.39	33.01	N.S.	
	Reducing sugars g/100 cc	1965	2.66	2.61	3.11	0.223	0.310
	Total sugars g/100 cc	1965	7.22	7.57	8.72	0.284	0.394

* Pulp %=weight of pulp/weight of fruit ×100.
** Juice %=Weight of juice/weight of fruit ×100.
*** The sugar of juice was measured by Refactometer.

5. The effect of shading on number and size of oil gland:

Though the difference in measurements of number, size of oil gland from different treatments were insignificant in 1964. But it was significant in 1965 as shown

in Table 5. In general it shows a tendency that shading would reduce the size and increase the number of oil gland which might induce the development of smooth peel surface of fruits.

Table 5. The effect of shading on the number and size of oil gland*

Treatments	No. of oil gland**		Size of oil gland (micron) μ	
	1964	1965	1964	1965
Semi-shading	30.35	28.87	524.62	499.88
Whole shading	30.75	29.87	500.87	479.75
Check	27.30	26.75	557.87	525.00
L.S.D. 5%	N.S.	0.425	N.S.	3.353
L.S.D. 1%		0.589		4.653

* All data in the table are averages of 8 replications.
** No. of oil gland per 0.5 centimeter square.

6. The effect of shading on size and grade of fruits:

In 1964 the size of fruit in the check plot was comparatively small as indicated in Fig. 5. Webber[14] had stated that the size and growth rate of citrus fruit was closely correlated with size and number of leaves per fruit on a given branch. We also found that less branches appeared in the check plot particularly in summer season while no branch emerged at all. The occurrence of large amount of small size fruit in the check plot from this experiment confirmed the finding of Webber

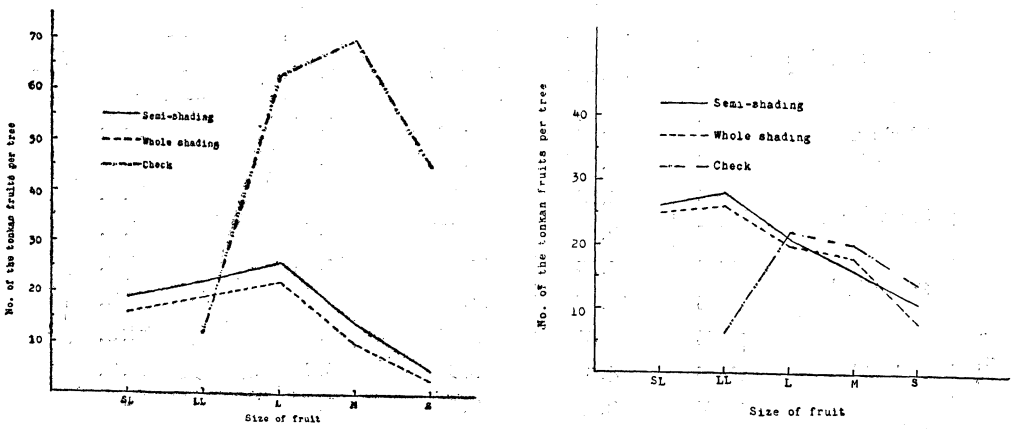

Fig. 5. Effect of shading on size and grade of fruit in 1964 (left) and 1965 (right). The classification of grade and size offruits was based on the standard stipulated by the Bureau of Inspection & Quarantine of Taiwan, i. e., SL, LL, L, M. S. represents above 25 cm, 23-25 cm, 21-23 cm, 19-21 cm and 17-19 cm, respectively.

7. The effect of shading on growth rate of Tonkan Orange:

The rate of fruit growth was successively surveyed from June 1964 to January 1966. It showed that the rate of growth increass noticeably in the months of August, September and October when the precipitation and temperature were high, and almost ceased to grow in dry July. These phenomina were especially true in the plots without shading. It suggested that shading might reduce the losses of

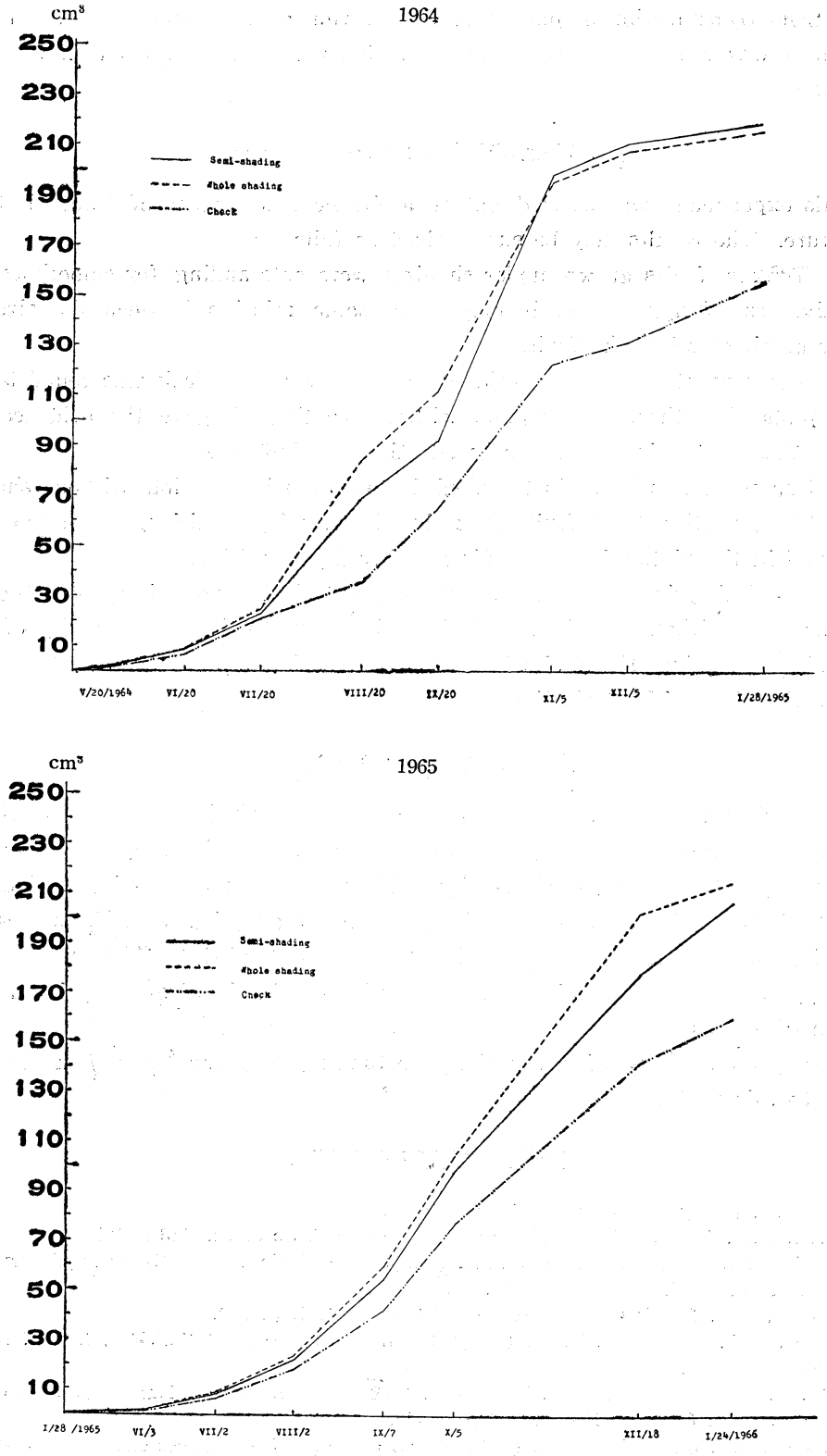

Fig. 6. The effect of shading on growth rate of Tonkan Orange.

water from transpiration of plant and evaporation of soil surface. In contrast to 1965, there was wet in July, the growth of citrus was normal even in the plots without shading.

SUMMARY AND CONCLUSION

This experiment was carried out at a site near sea coast of Tansuei, Taipei Prefecture. The results may be summarized as follows:

1. Tonkan fruits grown under shading were outstanding for smoothness and attractiveness of appearance, it may have some relation between the size and number of oil gland of the fruit.

2. The percentage of wind injured scurf appeared on fruit was found less on shaded plots than those in the plots without shading. It gave the evidence that interplanting of Acacia would also be effective as windbreak.

3. Sun scald was lower in the shaded plots than in the plots without shading.

4. The growth rate of fruit was reduced under dry condition, almost no growth was found in the plots without shading during dry condition.

5. The fruit juice obtained from shaded plots had more acidity than those of from the plots without shading. This is perhaps due to the late maturity of fruit under shading. Thus the fruits in shaded plots should be harvested later than those in the plots without shading.

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柑桔遮蔭試驗

第一報 遮蔭對桶柑風害、品質、果實成長之影響

嚴夢如 林澤海

(中文摘要)

1. 遮蔭可使果皮光滑，油胞小數目多，無遮蔭區則反是。
2. 遮蔭對風害有減少可能，經三年果實檢查結果顯示遮蔭區風疤率較無遮蔭區爲低。
3. 遮蔭對日燒病有顯著功效。
4. 遮蔭對果實成長有帮助，尤其七月間短暫之旱期有遮蔭區仍在成長，而對照區則生育有停滯現象。
5. 遮蔭柑桔果汁含量較多，但酸度酸些，可能因遮蔭有晚熟現象，與對照區同時採收尙嫌太早感。